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Influence of sodicity on growth, yield, quality and ionic composition of turmeric (*Curcuma longa* L.)

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Abstract

The influence of sodicity on growth, yield and curcumin content of turmeric (*Curcuma longa*) grown in Typic Natrustalfs soil at Banthra, Lucknow (Uttar Pradesh) was studied. The experiments were laid out in a split plot design with five levels of soil exchangeable sodium percentage (10, 20, 30, 40 and 50) as main plot treatments and four varieties (Local BRS, KTS-1, Rajendra Sonia and Meducar) as sub-plot treatments with three replications. The results showed that emergence of rhizomes was marginally affected due to sodicity. However, an adverse effect of sodicity on number of tillers clump^{-1} rather than plant height and number of leaves was observed. The estimated fresh rhizome yield on sodic soil followed the order of Meducar (4.8 t ha^{-1}) > Local BRS (4.4 t ha^{-1}) > KTS-1 (4.29 t ha^{-1}) > Rajendra Sonia (3.68 t ha^{-1}). The highest cured rhizome yield (0.96 t ha^{-1}) was obtained in Meducar followed by Local BRS > KTS-1 > Rajendra Sonia. The curcumin content was higher in Local BRS (9.6%) and Meducar (10.5%) than other genotypes grown in sodic soil. An accumulation of nutritionally adequate amount of potassium (K) and calcium (Ca) besides maintenance of greater K/Na (5.9) and Ca/Na (5.6) ratios in the foliage at ESP 20 indicated the potential of turmeric to withstand mild sodicity.

Keywords: *Curcuma longa*, curcumin, sodic soil, turmeric, yield.

Introduction

Turmeric (*Curcuma longa* L.) can be grown on a wide variety of soils and offers good scope of alternative land use of partially reclaimed salt affected soils lying barren in Uttar Pradesh provided appropriate agro-technology is developed without affecting its quality. Little information is available on the influence of exchangeable sodium percentage (ESP) on turmeric (Katiyar *et al.* 1999). Hence, the present study was undertaken to assess the growth, nutrient composition, yield and quality of turmeric as influenced by soil sodicity.

Materials and methods

The field experiments were conducted during *kharif* seasons of 2001-02 and 2002-03 at Banthra Research Station of National

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Botanical Research Institute, Lucknow (Uttar Pradesh). The soils in the experimental site belong to the family Typic Natrustalfs, sandy loam in texture with pH ranging from 8.6 to 10.0, EC seldom exceed 2 dSm^{-1} and ESP varied from 15 to 60. Soil characteristics showed medium organic carbon and total nitrogen, low available phosphorous and high available potassium status (Table 1). The experiment was laid out in a split plot design consisting of five main plot treatments of soil ESP, namely, 10 (control), 20, 30, 40 and 50 and four varieties of turmeric namely, Local BRS, Rajendra Sonia, KTS-1 and Meducar as sub-plot treatments with three replications. The desired levels of ESP were created by amending the soil with sodium carbonate/ gypsum based on GR values. Exact ESP was determined after treatment following standard method (Richards 1954). Rhizomes of uniform size (30-40 g) were sown at 8-10 cm depth in flat beds 30 cm apart during the first week of June every year. Before sowing, the rhizomes were treated with mancozeb 0.25% for 30 min to protect them from fungal attack. The rhizomes were sown in a manner to protect them from all sides by 1 m distance from each bed so that the neighbouring sodicity may not affect the treatment plots. Before sowing, the soil was fertilized with 40 kg N, 30 kg P_2O_5 and 40 kg K_2O ha^{-1}. Half dose of N and full dose of P_2O_5 and K_2O were applied at sowing. Remaining half dose of N was given 50 days after planting. Cultural operations including irrigation and plant protection measures were followed uniformly. The crop was harvested in mid February each year. Observations on germination at 5 days interval up to 15 days till maximum sprouting occurred and vegetative growth such as plant height, number of leaves and tillers $clump^{-1}$ $plant^{-1}$ and yield of rhizome was recorded at harvest. At harvest, samples of leaf, root and rhizome were collected separately. They were washed with deionized water, dried in an oven at 70^0 C and powdered in a mill and analyzed for determination of major elements. N was estimated by macro Kjeldahl method using a Tecator Kjeltec Auto 1030 Analyzer; P by colorimetric procedure

Table 1. Soil analysis before planting of turmeric

Treatment	pH (1:2 Soil)	EC (d Sm^{-1})	OC (%)	Total N (%)	Available P (kg ha^{-1})	Available K (kg ha^{-1})	CEC (c mol kg^{-1})	ESP
10 ESP	7.59 ±0.15	0.67 ± 0.21	0.56 ± 0.08	0.132±0.004	18.96±1.77	951.60±62.27	20.81±0.72	11563±1.02
20 ESP	8.60 ± 0.13	0.87 ± 0.21	0.56 ± 0.05	0.104±0.003	21.66±3.61	881.77±107.70	18.90±1.01	20.69±2.28
30 ESP	9.01 ± 0.16	0.69 ± 0.07	0.44 ± 0.04	0.089±0.004	19.47±2.25	801.13±47.39	16.71±0.74	30.99±1.51
40 ESP	9.36 ± 0.33	0.58 ± 0.03	0.39 ± 0.11	0.085±0.012	13.17±4.31	716.78±62.12	14.81±0.51	41.03±1.44
50 ESP	9.67 ± 0.12	0.55 ± 0.03	0.34 ± 0.04	0.080±0.002	6.43±0.30	683.93±30.69	14.94± .62	50.31±3.63

Values indicate mean ± SD; EC=Electrical conductivity; OC=Organic carbon; CEC=Cation exchange capacity; ESP=Exchangeable sodium percentage using vanadomolybdophosphoric yellow colour method (Richards 1954); K, Na, Ca and Mg by flame photometer methods (Jackson 1967). The data was subjected to statistical analysis for test of significance (Panse & Sukhatme 1961). Curcumin contents in fresh rhizome was extracted in absolute alcohol by soxhlet extraction and estimated colorimetrically (Sadasivam & Manickam 1992).

Results and discussion

Sprouting

Sprouting started by the 5th day and reached maximum on 15th day after planting (Fig.1). Maximum emergence (100%) was observed in all varieties except Meducar where it was 96% in control (ESP 10) and varied from 85% to 96% at ESP 50 showing slight decline with rising of soil ESP. Generally, sprouting of turmeric rhizome takes place in about 2 weeks (Ravindran *et al*. 2007). However, it depends on several factors like size of rhizome, sowing temperature and time and depth of planting. Emergence of turmeric propagules is reduced if their size is <30 g and is delayed with increasing planting depth but emerges normally when planted at >8 cm or 4" depth since sufficient soil moisture is available at this depth. Further, dormancy of rhizome is broken naturally from April–June and a temperature varying from 25^0 C to 35^0 C is

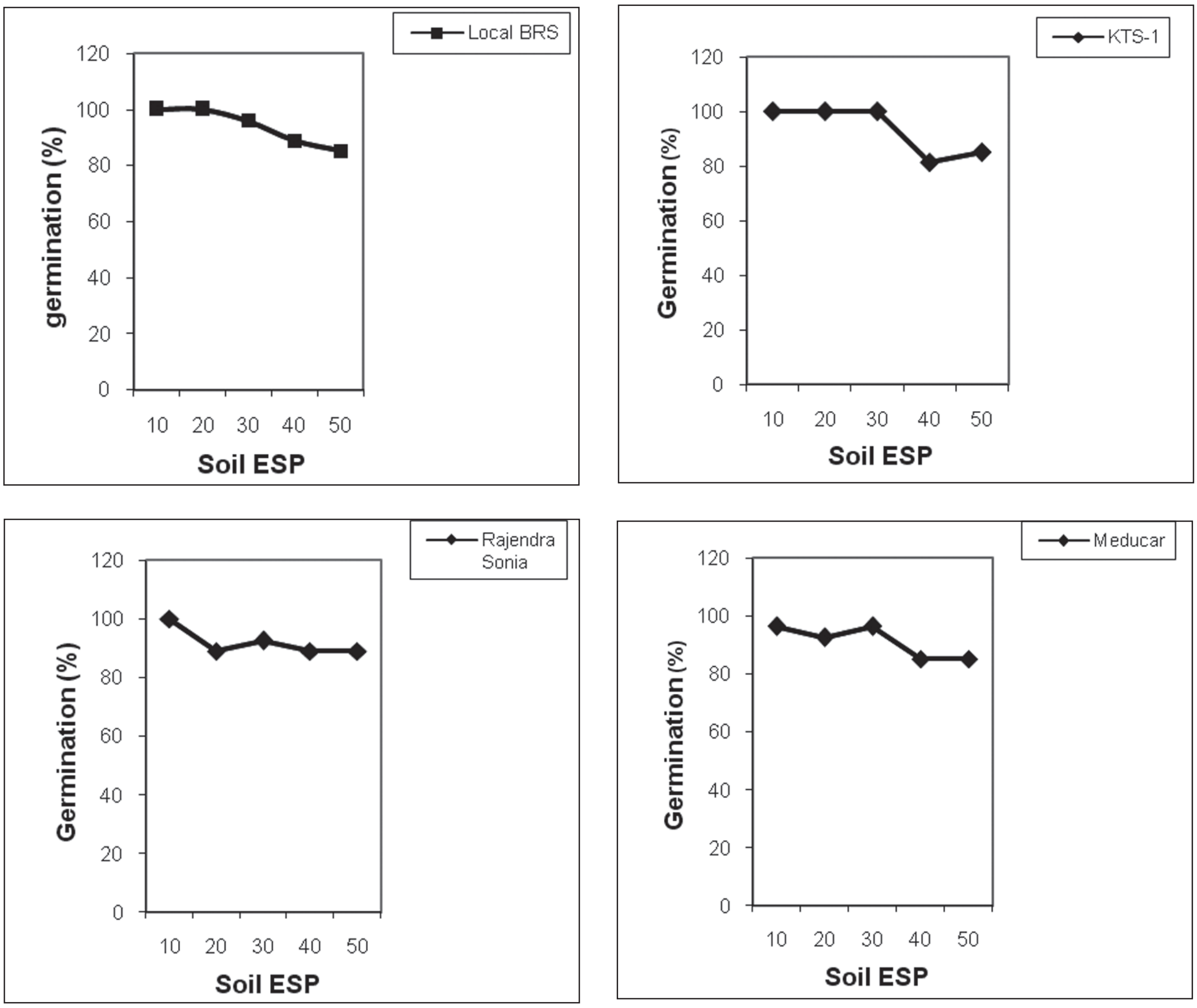

Fig. 1. Germination (%) of turmeric varieties grown at different levels of soil ESP

required for optimum and favourable physiological activity, metabolism of storage reserve and enzyme synthesis in buds for sprouting (Ishimine *et al.* 2004). In the present study, good emergence was noticed, except at higher soil sodicity leading to slight decrease in sprouting due to salt stress. Sodicity tolerance of crops is affected by many factors like variety, growth, stage and environment and in our study turmeric appears to be tolerant enough at germination stage.

Vegetative growth

Maximum vegetative growth was observed at ESP 10 (control) which decreased with increasing soil ESP. Mean plant height varied from 85.8 cm (Rajendra Sonia) to 91.4 cm (Local BRS) at ESP 10 (control) and varied from 28.8 cm (Rajendra Sonia) to 53.2 cm (Meducar) at ESP 50. There was less reduction in plant height of Meducar (40%) than in Rajendra Sonia (66%) at the highest soil sodicity (Table 2). Maximum number of leaves was produced by Rajendra Sonia and Meducar followed by KTS-1 and Local BRS at ESP 10 (control). The order of decrease in mean number of leaves was Meducar > Local BRS > KTS-1 > Rajendra Sonia at ESP 50. The highest average number of tillers clump^{-1} was noticed in Rajendra Sonia (2.22) and the least in Local BRS at control. It is interesting to point out that no tillering took place in KTS-1 at ESP 40 and ESP 50 (Table 2). The results thus, clearly show the adverse effect of sodicity on tillers rather than number of leaves and plant height. These variations in growth may be attributed to differential genotypic characteristics of turmeric (Chaudhary *et al.* 2006). Besides, micronutrients like Zn and Fe although not investigated here, may adversely affect the growth parameters in addition to sodicity stress of the soil (Dixit & Srivastava 2000).

Table 2. Vegetative growth of turmeric grown at different levels of soil ESP

Treatment	Local BRS	KTS-1	Rajendra Sonia	Meducar
	Plant height (cm)			
ESP 10	91.4	86.2	85.8	87.6
ESP 20	62.8	56.0	47.0	78.5
ESP 30	53.9	55.0	43.1	79.8
ESP 40	42.7	50.8	41.7	52.9
ESP 50	42.3	42.2	28.8	53.2
CD (P=0.05)	34.6	27.6	16.1	27.0
	Number of leaves plant^{-1}			
ESP 10	7.00	7.33	8.00	8.00
ESP 20	6.66	6.66	5.66	7.33
ESP 30	6.00	6.66	5.33	6.66
ESP 40	5.66	5.66	5.33	6.33
ESP 50	5.66	5.33	4.33	6.00
CD (P=0.05)	1.05	1.29	1.64	0.94
	Number of tillers plant^{-1}			
ESP 10	0.33	0.56	2.22	1.00
ESP 20	0.23	0.10	0.96	1.00
ESP 30	0.23	0.10	0.76	0.53
ESP 40	0.10	0.00	0.76	0.56
ESP 50	0.10	0.00	0.66	0.10
CD (P=0.05)	0.002	0.212	0.833	0.667

ESP=Exchangeable sodium percentage

Studies on the response of foliar spray of Zn 0.5% ($ZnSO_4$), Cu ($CuSO_4$), Fe ($FeSO_4.7H_2O$) and their mixtures done thrice at 60 days interval after sowing of turmeric (var. Local BRS) grown in sodic soil (ESP 20) at the same farm indicated a remarkable effect of Zn and mixture of micronutrients than Cu and Fe on plant height and yield of rhizome (Table 3). wide variability of yield in different states of India and ranges from 4.59 t ha^{-1} to 95.0 t ha^{-1} as per the reports compiled from several research papers (Kandiannan *et al.* 2002). In the present study, the maximum fresh rhizome yield of Meducar at 20 ESP as indicated by the interaction (ESP x Var) was 6.9 t ha^{-1} though far less from the range of yield in different states. The yield is at par with that of 5.7 t ha^{-1} obtained from turmeric grown in sodic soil (Katiyar *et al.* 1999). Assuming 50% reduction in yield as criterion for sodicity tolerance, the variety Meducar appears to be mildly tolerant. The highest cured rhizome mean yield was 0.96 t ha^{-1} for Meducar followed by 0.88 t ha^{-1} for Local BRS, 0.85 t ha^{-1} for KTS-1 and 0.73 t ha^{-1} for Rajendra Sonia. The variation in curing quality depends on variety, moisture content and maturity duration of crop (Rao *et al.* 1975; Chaudhary *et al.* 2006).

Table 3. Response of turmeric to foliar spray of micro-nutrients

Treatment	Plant height (cm)	Number of leaves plant^{-1}	Yield (g m^2)
Control	87.0	5.40	235.0
Zn 0.5%	97.0	5.40	580.0
Cu 0.5%	93.0	4.97	367.0
Fe 0.5%	94.0	5.41	367.0
Zn 0.5% + Cu 0.5% + Fe 0.5%	94.0	5.25	467.0
CD (P=0.05)	4.0	0.58	48.0

Rhizome yield

The mean (two years) yield of fresh rhizome of turmeric varied from 783 g m^2 in var. Meducar to 1033.3 g m^2 in var. Rajendra Sonia in control (ESP 10). It ranged from 89.3 g m^2 in var. Rajendra Sonia to 255 g m^2 in var. Local BRS at highest ESP 50 showing a drastic reduction in yield with rising sodicity. However, the varietal differences were not significant but the effect of different ESP levels was significant. The interaction between ESP x Variety showed significant differences among some of them except a few cases were not on pooled basis. There was a significant interaction of var. Rajendra Sonia followed by Local BRS at ESP 10. However, all the varieties did not perform well beyond 20 ESP and var. Meducar followed by Local BRS had highly significant interaction with ESP 20. Thus, the best performing variety was Meducar. The calculated yield on sodic soil followed the order of var. Meducar (4.8 t ha^{-1}) > Local BRS (4.4 ha^{-1}) > KTS-1 (4.29 t ha^{-1}) > Rajendra Sonia (3.68 t ha^{-1}) (Table 4). In general, yield of fresh rhizome on normal soil varies from 5.0 t ha^{-1} to 16.7 t ha^{-1} depending on the variety, spacing, use of manure and fertilizers (Kurian & Valsala 1995; Islam *et al.* 2002; Hossain & Ishimine 2007; Olojede *et al.* 2009). However, there is

Curcumin content

The curcumin content in the fresh rhizome varied between 5.75% (KTS-1) and 7.10% (Meducar) in non sodic soil (ESP 10) and from 5.05% (KTS-1) to 10.5% (Meducar) in sodic soil (ESP 20) (Fig. 2). Curcumin content of KTS-1 and Rajendra Sonia decreased under sodic soil conditions whereas its content in Local BRS and Meducar increased in sodic soil. The variation in curcumin contents may be attributed to influence of climate, soil nutrition and genotypes (Kumar *et al.* 1992; Kurian & Valsala 1996).

Nutrient concentration

In general, major nutrient concentrations in different parts of the plant decreased with

Table 4. Yield (fresh rhizome) of turmeric grown at different levels of soil ESP

Treatment	Yield (g m^{-2})
Variety	
Local BRS	440.6
KTS-1	429.3
Rajendra Sonia	368.0
Meducar	480.0
CD (P=0.05)	104.0
ESP level	
10	904.1
20	475.0
30	332.7
40	232.0
50	203.6
CD (P=0.05)	176.8
Interaction	267.6

Variety	Interaction of sodicity levels and cultivar yield (g m^{-2})				
	10 ESP	20 ESP	30 ESP	40 ESP	50 ESP
Local BRS	916.7	493.3	273.3	264.7	255.0
KTS-1	886.7	440.0	420.0	250.0	150.0
Rajendra Sonia	1033.3	276.7	244.3	196.7	89.3
Meducar	780.0	690.0	393.3	216.7	320.0

ESP=Exchangeable sodium percentage

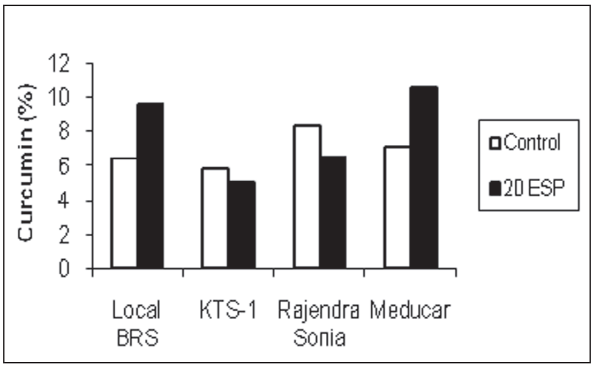

Fig 2. Curcumin content of turmeric varieties grown in non-sodic and sodic soils (ESP 20)

increasing soil ESP. However, it was greater in rhizome except for Na and for P which was greater in leaf tissue. The sodicity tolerance of a plant depends upon its ability to exclude Na and absorb nutritionally adequate amount of K and Ca in sodic soil (Bekke & Volkmar 1995; Epestein 1998). The accumulation of K (11.6 mg g^{-1}) and Ca (10.9 mg g^{-1}) in the foliage and maintenance of greater K/Na (5.9) and Ca/Na (5.6) ratios at ESP 20 (sodic soil) probably indicates salt tolerance mechanism in turmeric (Table 5). It is generally observed that when plant is grown in saline/sodic soil conditions the mineral composition of it is altered and the growth of it suffers more due to ion imbalance stress. In the present study accumulation/exclusion of Na ion does not show any deficiency/toxicity during growth and development.

The study indicated that turmeric is tolerant enough to sodicity at germination but was affected adversely at tillering stage. The variety Meducar produced higher fresh and cured rhizomes including curcumin content than other varieties. The crop showed Na exclusion mechanism and absorbed nutritionally adequate K and Ca and thus, has potential to withstand mild degree of sodicity.

Table 5. Nutrient composition of different parts of turmeric (var. Meducar) grown in different levels of soil ESP

Treatment	N (mg g^{-1})	P (mg g^{-1})	K (mg g^{-1})	Ca (mg g^{-1})	Mg (mg g^{-1})	Na (mg g^{-1})	K/Na	Ca/Na
				Leaf				
ESP 10	5.50±0.15	1.39±0.12	13.58±1.67	12.00±0.61	6.20±0.48	1.42±0.57	9.56	8.40
ESP 20	7.50±0.20	1.17±0.07	11.63±2.53	10.92±2.55	6.40±1.49	1.96±0.19	5.90	5.60
ESP 30	6.00±0.08	0.86±0.14	11.16±3.55	8.90±2.94	7.84±1.69	1.90±0.16	5.87	5.70
ESP 40	5.50±0.05	1.05±0.17	11.04±1.41	11.20±0.8	8.83±1.01	2.25±0.25	4.90	5.00
ESP 50	6.00±0.15	0.98±0.05	15.35±2.13	10.92±0.59	3.45±0.67	2.52±0.77	4.10	3.53
				Root				
ESP 10	2.50±0.05	Tr	19.00±2.34	41.00±6.63	14.00±1.87	8.00±1.18	2.37	5.10
ESP 20	5.00±0.07	1.00±0.01	20.00±3.14	37.00±4.12	10.00±1.74	8.00±1.74	2.50	4.60
ESP 30	4.00±0.11	1.00±0.02	25.00±2.80	35.00±3.56	11.00±1.18	10.00±2.02	2.50	3.50
ESP 40	5.50±0.18	1.00±0.01	15.00±2.50	32.00±5.16	7.00±1.80	11.00±2.45	1.36	2.70
ESP 50	4.50±0.21	1.00±0.02	13.00±1.70	31.00±4.12	7.00±1.47	15.00±3.13	1.00	2.40
				Rhizome				
ESP 10	23.50±5.56	2.00±0.02	21.00±2.96	32.00±6.70	12.00±0.67	3.00±1.11	7.00	10.60
ESP 20	23.00±3.97	2.00±0.05	20.00±4.80	28.00±8.20	11.00±0.65	4.00±0.75	5.50	7.00
ESP 30	22.50±4.80	2.00±0.01	20.00±3.79	16.00±4.25	4.00±0.50	4.00±1.85	5.00	4.00
ESP 40	31.00±3.79	2.00±0.01	20.00±5.84	16.00±4.12	3.00±0.25	5.00±0.35	4.00	3.20
ESP 50	27.00±5.68	2.00±0.01	15.00±3.70	13.00±3.50	1.00±0.05	6.00±1.80	2.50	2.10

Values indicate mean ± SD; ESP=Exchangeable sodium percentage

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